INTEGRATED SCIENCE PLAN

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Introduction

This *Integrated Science Plan* (ISP) provides an organizing framework of scientific information and knowledge needed by managers and policy makers restoring the South Florida Greater Everglades ecosystem. This framework formalizes a multi-institutional network through which collective efforts are focused and information is shared. Timely scientific information must be available to guide decisions at each of a series of critical stages in the redesign of the Central and Southern Florida (C&SF) Project. The term "science" in this context includes biological, chemical, physical, and social sciences, because all play an integral role in development of a sustainable restoration plan.

Scientists have two distinct roles in the restoration process. The first role is to ensure that the best existing scientific knowledge is available in the planning and decision making processes. The second role is to acquire critical new information necessary to reduce uncertainty and improve the probability of meeting restoration goals . Scientists must provide timely and well-focused scientific information in an appropriate form to ensure that the best scientific knowledge currently available is used to plan and evaluate restoration actions. It is critical that scientists be actively engaged in the restoration process while, at the same time, their scientific investigations augment knowledge about the ecosystem. It is also critical that managers and regulators be aware of scientific recommendations. Decisions are being made continuously in the multiyear process of project design and implementation, and a scientific basis for these decisions is the key to restoration success.

Background

The ecological integrity and functionality of the Greater Everglades and coastal ecosystems is the theoretical target for restoration. The natural system supported clean and abundant water supplies, large populations of wading birds, fish, and other wildlife, and landscape patterns that made South Florida's Greater Everglades and coastal ecosystems unique. Using quantitative estimates of natural system conditions as theoretical targets for the remaining natural areas will ensure that changes brought about by restoration efforts are in the right direction. This approach does not favor one species or community over another, but rather the mix of species that occurred here naturally. The objective of restoration is to recapture the defining characteristics of the diverse ecosystems within South Florida's Greater Everglades and coastal landscape.

Hydrologic restoration is viewed as an important prerequisite to ecosystem restoration. For this reason, the *Comprehensive Everglades Restoration Plan* (CERP), which is a redesign of the C&SF water management project, is the keystone of the restoration process. However, other measures, such as water quality improvement, also will be necessary. The working hypothesis of the South Florida ecosystem restoration effort is that a restored, sustainable ecosystem will follow from restoring a more ecologically beneficial hydrologic regime, improving water quality, recovering natural fire patterns, and controlling exotic species. In reality, because of the fifty percent reduction in the spatial extent of the Everglades and the irreversible changes to South Florida's wetlands, complete restoration is not possible. Rather, the restoration program is expected to shift the currently degraded system substantially in the direction of a natural system. How far the shift occurs towards natural composition and function depends on employment of an *adaptive assessment* process being implemented under the CERP. This is a process whereby projects are evaluated, refined, and supported by a strong, continuous multi-agency scientific research program and a comprehensive regional monitoring program.

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Objectives

The following systemwide objectives for South Florida ecosystem restoration were recommended in a 1993 *Science Subgroup Report*. They are equally applicable today. The purpose of this ISP is to organize the scientific basis for achieving these regional-scale objectives:

- Restore water quality by reducing nutrients and contaminants.
- Restore natural relationships between rainfall and hydropatterns.
- Restore timing and volume of freshwater flow through the system and into estuaries.
- Restore natural sheet flow, reduce compartmentalization, and restore inter-regional
- linkages.
- Restore dynamic water storage capacity.
- Reduce habitat fragmentation and restore ecological connections.
- Reestablish sustainable locally breeding wildlife populations.
- Recover endangered and threatened species.
- Halt/reverse expansion of invasive nonnative plant species.
- Halt/reverse expansion of invasive nutrient-loving native plant species.
- Increase spatial extent of wetlands.
- Increase natural biological diversity and landscape heterogeneity.
- Restore native vegetation communities, replacing lost communities.
- Restore natural periphyton communities.
- Restore coral cover.
- Restore biological productivity of wetlands, estuaries, reefs, and fisheries.
- Restore self-maintaining properties of natural and human systems.
- Increase the beneficial linkages of agricultural, urban, and natural ecosystems.

Approach

Issues associated with restoration of South Florida's natural systems are so large in scale and so geographically, ecologically, and socioeconomically complex that a broadly integrated planning and coordinating process is necessary to address them.

Natural and social scientists must pursue innovative approaches that will concurrently strengthen both human and environmental goals and acknowledge the concerns of the various interest groups. With so many issues, scientific disciplines, and stakeholders involved, a collaborative, scientific process must be utilized to seek consensus on the diverse set of technical issues for the restoration effort to be successful.

The ISP provides a framework for future detailed planning. It assumes that restoration goals can only be achieved through multidisciplinary and multi-agency cooperation in identifying and resolving complex technical issues. The scientific community will make its strongest contributions by employing inclusive processes to create scientific consensus positions on the major issues. The Science Coordination Team (SCT), organized under the South Florida Ecosystem Restoration Task Force Working Group (the working group), has the lead responsibility for encouraging and coordinating integration of all scientific efforts conducted in support of the South Florida ecosystem restoration.

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Science Roles

The two major goals for utilizing science in the South Florida restoration effort are (1) to acquire new information required to fill gaps in scientific knowledge critical in meeting the restoration goals, and (2) to create real-time data-collection networks by which scientists can support managers and policymakers in planning, monitoring, and evaluating restoration programs. The parallel processes addressing these goals are linked through the development and application of *conceptual ecological models* specifically developed for South Florida ecosystems.

Science Coordination Structure

A science coordination structure has evolved to coordinate the acquisition and synthesis of scientific knowledge and to facilitate interaction between the scientific and management communities in planning and evaluating projects related to restoration. The science coordination structure consists of four science groups or entities.

Science Coordination Team (SCT)

The SCT, established by the working group facilitates integration and coordination of the interagency science program and science application. Membership on the SCT is from agencies and entities of the working group and members of the public.

Selection of SCT Priorities for FY2000-2001

Throughout its first three years of operation, the SCT realized that the original charter was ambitious, given the amount of financial and human resources dedicated to the effort. In order to become more effective and to realistically assess its capabilities, the SCT began a prioritization process in February 2000, with a list of almost sixty possible priorities. Following much discussion and deliberation, the SCT narrowed the possible priorities down to eighteen topics. The SCT further prioritized these topics using the following criteria: topical scope, short- versus long-term commitment, a realistic assessment of the amount of time each SCT member can contribute to any priority topic, and timing relative to restoration needs.

In May 2000, after a discussion of each topic, the following five topics were selected as priority science issues for FY2000-2001: (1) planning and implementation of the Greater Everglades Ecosystem Restoration Conference (GEER); (2) support for the Committee on the Restoration of the Greater Everglades Ecosystem (CROGEE); (3) water quality; (4) the role of science in the CERP (through participation in Restoration Coordination and Verification (RECOVER) Team activities; and (5) water flow, function, and topography. Some details on several of these topics are briefly described in some of the following sections of this report.

Regional Science Groups

Regional science groups have been developed in several subregions in South Florida where a number of federal and state agencies and universities are working and share jurisdiction. The prototype for these regional science groups has been the Program Management Committee

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(PMC) for the Interagency Florida Bay Science Program. This PMC has been coordinating research in Florida Bay since 1994 in accordance with a strategic science plan organized around five central questions related to the structure, function, and restoration of Florida Bay. This PMC consists of designated representatives of the state and federal agencies conducting or funding research in Florida Bay, and it receives guidance from a standing scientific oversight panel whose members attend the Florida Bay Science Conference and topical workshops and regularly review the strategic science plan. Recently the working group requested this PMC to expand its coverage to adjacent coastal areas and to include agencies conducting research in Biscayne Bay and along the southwest coast (coastal portions of subregions 3 and 5). A subcommittee of this PMC has begun to develop a strategic science plan for Biscayne Bay.

Following the Florida Bay PMC prototype, the Southwest Florida Science Group has prepared a regional science plan for subregion 5. Other subregional science plans, also following the PMC prototype, are being developed for the subregions where science information needs require coordinated multi-agency science programs.

National Academy of Sciences

In coordination with the South Florida Ecosystem Restoration Task Force (the task force), the National Academy of Sciences created the Committee on the Restoration of the Greater Everglades Ecosystem (CROGEE). CROGEE is charged with providing a multiyear, systemwide peer review of the science underpinning of the CERP, and with reviewing the science processes used to support other South Florida restoration programs. CROGEE is linked to the SCT through a liaison team established by the task force executive office, the working group, and the SCT.

RECOVER (Restoration Coordination and Verification) Team

RECOVER is the primary entity responsible for application of scientific knowledge to planning and implementation of CERP water-management projects. The role of RECOVER is to organize and apply scientific and technical information in ways that are most effective in supporting the objectives of the CERP. RECOVER links science and the tools of science to a set of systemwide planning, evaluation, and assessment tasks. These links provide RECOVER with the scientific basis for meeting its overall objectives of evaluating and assessing CERP performance, refining and improving the plan during the implementation period, and ensuring that a systemwide perspective is maintained throughout the restoration program.

In order to establish and maintain an effective link between science and the CERP, the Central and Southern Florida Project Restudy Team created a process known as the Applied Science Strategy. The RECOVER team is responsible for the coordination and application of the components of the Applied Science Strategy during the implementation of the CERP. The major components of the science strategy are conceptual ecological models, performance measures and restoration targets, a systemwide monitoring and research program, and an adaptive assessment protocol.

RECOVER comprises six multi-agency and multidisciplinary task teams organized by the Corps of Engineers and its local sponsor, the South Florida Water Management District (SFWMD), to help implement the CERP. The structure of RECOVER is described in detail in the implementation plan for the CERP. A brief description of the six teams follows. To facilitate

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cooperation and coordination between the SCT and RECOVER, some scientists serve jointly on the SCT and RECOVER teams.

Adaptive Assessment Team (AAT)

The Adaptive Assessment Team primarily is responsible for creating, refining and providing the *Monitoring and Assessment Plan* (MAP). The MAP contains a description of regional monitoring plans for Lake Okeechobee, the northern estuaries (Caloosahatchee and St. Lucie), the greater Everglades basin (Everglades ridge and slough, Everglades marl prairies, southern mangrove estuaries, eastern big Cypress), and the southern estuaries (Florida Bay and Biscayne Bay), water quality, and water supply and flood protection. The MAP also documents a set of conceptual ecological models for the total system and for each of the major physiographic regions of South Florida. The AAT also creates and refines a set of attribute-based biological performance measures for the CERP. Another important function of the AAT is to design and review the systemwide monitoring and data management program needed to support the CERP. The AAT uses the information coming from the systemwide monitoring program to assess actual system responses as components of the CERP are implemented. Finally, the AAT produces an annual assessment report describing and interpreting these responses.

Regional Evaluation Team (RET)

The Regional Evaluation Team of RECOVER primarily is responsible for reviewing and revising the set of systemwide stressor-based performance measures and restoration targets and for resolving technical issues pertaining to the performance measures. The RET also conducts systemwide analyses of the CERP using the latest refinements in predictive tools (e.g., SFWMM, ELM).

Model Development and Refinement Team (MRT)

The Model Development and Refinement Team is charged with the overall task of ensuring that the predictive tools used to conduct the evaluations of the CERP components are consistent with the scales and targets set by the performance measures for each component. This team oversees the quality of physical, water quality, and ecological models and coordinates the resolution of technical issues pertaining to the models. Any necessary refinement or enhancement of systemwide tools (e.g., the South Florida Water Management Model) will also fall under this team's purview.

Water Quality Team (WQT)

The Water Quality Team has the responsibility for coordinating the Applied Science Strategy for water quality, and for developing and implementing a water-quality strategy at both the regional and project levels. It crosses all other RECOVER teams' responsibilities by providing the water quality component to their products, as well as having responsibility for independent projects. Tasks of the WQT include the development and review of water-quality performance measures, development of the water-quality components of the CERP systemwide monitoring plan, providing input into the annual assessment of system responses, particularly as they relate to

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water quality, and serving as a link between RECOVER and project delivery teams to ensure local water quality for projects is appropriately addressed and coordinated with systemwide water-quality performance measures and targets.

Operations Planning Team (OPT)

The Operations Planning Team has the lead role for coordinating and resolving systemwide operational issues associated with the implementation of the CERP. The team supports the Project Delivery Teams in the design of operational criteria and water control plans for each of the CERP components. The OPT also works with the Adaptive Assessment Team in reviewing hydrological responses during the implementation period. It also coordinates or recommends interim operational criteria wherever these changes may provide enhancements in the performance of the plan before all components of the plan are in place.

Comprehensive Plan Refinement Team (CPR)

The Comprehensive Plan Refinement Team has the lead responsibility for recommending refinements and improvements to the CERP throughout the implementation period, as new information that identifies where, how, and why these improvements should be made becomes available. It links closely with other RECOVER teams to identify needed plan refinements and a means for incorporating these refinements into the design. The CPR team is an ad hoc team that is formed each time there is a need to address a systemwide performance issue.

Building Scientific Knowledge

Conceptual Ecological Models

RECOVER manages the development of ten conceptual ecological models proposed by interdisciplinary science teams. These conceptual models, identified below, identify societal drivers (e.g., water management), resulting ecological stressors (e.g., altered hydropatterns), and their effects on ecological systems (e.g., reduced fish production). They are more like risk-assessment models than quantitative ecological models. They are designed to focus attention upon the restoration hypotheses explaining the currently degraded condition of various ecosystems or regions in South Florida. Each model identifies principal biological attributes (e.g., endpoints and indicators) that characterize the "health" of each landscape or ecosystem and reflect important ecological and societal values of the system. Formulation, examination, and refinement of hypotheses embedded in the models are expected to become the primary means for identifying gaps in current knowledge, setting future research priorities, and guiding modifications to restoration efforts. Research priorities established during the conceptual ecological model workshops addressed specific scientific needs associated with modeling, monitoring, and cause-and-effect scientific studies. Emphasis of new work will be on filling information gaps. The conceptual ecological models are dynamic and are being reviewed continually and revised as additional data and knowledge about the ecosystem and its response to restoration efforts emerge. Beyond the CERP, recommendations developed through this process are presented to the working group through the SCT.

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The ten conceptual ecological models (nine physiographic regions plus one total system model) are thoroughly described in the MAP developed by the RECOVER AAT. The ten conceptual ecological models are listed below:

- Everglades Ridge and Slough Conceptual Model
- Everglades Calcitic Wetlands Conceptual Model
- Big Cypress Conceptual Model
- Everglades Mangrove Estuary Conceptual Model
- Florida Bat Conceptual Model
- Biscayne bay Conceptual Model
- Caloosahatchee Estuary Conceptual Model
- St. Lucie Estuary and Indian River Lagoon Conceptual Model
- Lake Okeechobee Conceptual Model
- Total System Conceptual Model

The review of these conceptual ecological models by the interdisciplinary science teams identified common issues, hypotheses, and linkages across the models, which grouped into five major themes or restoration expectations. Each of the five themes was developed into an integrated monitoring and assessment package. The five packages constitute the framework of the MAP and cover several physiographic regions as shown in the following table:

MAP Package	Physiographic Regions
1. Wetland Landscape Package	1. Ridge and Slough 2. Calcitic Wetlands 3. Big Cypress 4. Mangrove Estuary
2. Wetland Trophic Relationships Package	1. Ridge and Slough 2. Calcitic Wetlands 3. Big Cypress 4. Mangrove Estuary
3. Estuarine Epibenthic Communities, Habitats, and Indicators Package	1. Florida Bay 2. Biscayne Bay near-shore Environment 3. Mangrove Estuary Coastal Lakes 4. Caloosahatchee Estuary 5. St. Lucie Estuary / Indian River Lagoon 6. St. Lucie Headwater
4. Effects of Stage and Phosphorus on Lake Littoral and Pelagic Zones Package	1. Lake Okeechobee
5. Biota of Special Concern Package (not covered by other packages)	1. Crocodile (Biscayne Bay and Mangrove Estuary) 2. Cape sable Sparrow (Calcitic Wetlands) 3. Manatee (Biscayne Bay and Caloosahatchee) 4. White-tailed Deer (Big Cypress) 5. Dolphin Health (Biscayne Bay) 6. Fish Health (Biscayne Bay and St. Lucie/ Indian River Lagoon

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Communication

The SCT facilitates communication among the many scientists and agencies conducting or supporting restoration program science. Multidisciplinary science conferences have been organized to present ongoing research, while topical workshops have been used to focus an exchange of information and ideas on specific technical issues. For example, in 1999 the SCT sponsored the South Florida Ecosystem Restoration Science Forum to promote communication between scientists and managers. The SCT scheduled the Greater Everglades Ecosystem Restoration Science Conference in December 2000, with the primary focus of facilitating exchange between scientists. The Science Forum and Science Conference are sponsored in alternate years.

Integrated Data Management

An inventory of all monitoring activities occurring throughout the CERP area was completed by a private contractor in April 2002 under a contract with the Corps of Engineers. All hard copies of data received by the contractor were manually entered into a database. The contractor also committed to merge the four metadata (data about the data) databases made available by different state and federal agencies. The final inventory report produced by the contractor has an index of the monitoring data and a bibliography with approximately 8,000 entries. Other inventories are being conducted, and available databases are being archived in a multigovernmental database-management system accessible through the Internet. Metadata also are being compiled and supplied through the USGS South Florida Information Access (SOFIA) web site (http://www.sofia.usgs.gov). SOFIA is routinely enhanced and updated and has become one of the most complete databases on restoration related science projects. A guide to the information available from each database is available and continually updated. The process of accomplishing this critical activity was initiated with a multi-agency metadata workshop organized by the USGS under the aegis of the SCT in March 2000.

Applying Scientific Knowledge

An applied science strategy is being used to help plan and evaluate restoration projects. This science strategy was initially applied in the selection of alternative and improved redesigns of the South Florida water management system to help restore the ecological health and integrity of the Everglades. In addition, a multi-species management plan was developed to ensure that the future of each threatened and endangered species is evaluated in the context of the future quantity and quality of its habitat.

Applied Science / Adaptive Assessment Strategy

A science-based strategic process has been designed to provide a comprehensive framework for organizing existing scientific information and knowledge about the natural systems in South Florida into formats which are most applicable to the planning, evaluation, and assessment of restoration projects at regional and systemwide scales.

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The applied science / adaptive assessment strategy has five major components: (1) development and continuous improvement of conceptual models based on current scientific knowledge, (2) development and updating of performance measures for key stressors and attributes (indicators) in the conceptual models, (3) design of a systemwide science program that consists of (a) long-term monitoring and data collection to track ecosystem status and trends, (b) cause-and-effect scientific studies designed to increase understanding of ecosystem responses to restoration, (c) simulation modeling to provide a framework for assessing the degree of scientific understanding, and (d) peer review to ensure high-quality and credible science, (4) annual assessment, based upon monitoring these performance measures, of the degree to which restoration is meeting expectations, and (5)providing feedback to planners and engineers on where modifications in design are needed to meet targets.

Each component depends on the creation of scientific consensus, achieved through a series of technical workshops organized across multi-agency and multidisciplinary lines and the use of an independent peer review process. Research will be required (1) to reduce uncertainty in predictions, (2) to understand the causes of change, (3) to distinguish causal connections from chance correlations, and (4) to explain change that is not exactly as predicted. Simulation models developed in the science program will be used in this adaptive process to help predict how well specific restoration plans can be expected to meet the targets set for the performance measures and to interpret measured responses against a background of annual and internal variation in major influencing environmental factors, such as rainfall.

Applying Conceptual Ecological Models

The ultimate purposes of the conceptual ecological models are (1) to convert the broad, policy-level objectives that have been established for each restoration program into specific, measurable indicators, (2) to develop a suite of hypotheses that describe the major ecological responses to the restoration projects, and (3) to use the models to identify the performance measures needed to evaluate each restoration plan. The hypotheses become the basis for the restoration plans by identifying the improvements in hydrologic conditions and water quality that are necessary to achieve the restoration objectives. These conceptual models identify the major stressors and biological attributes (e.g., indicators) expected to best characterize the system's response to specific restoration actions. Hydrologic and biologic performance measures and a systemwide ecological monitoring program will be based on the relationships expressed in these conceptual models.

As specific restoration projects are planned and designed, simulation models are used to predict how well each alternative plan is likely to perform. Once the selected plan is implemented, a well-focused monitoring program will measure how well the key attributes in each system respond, according to their performance measures. Cause-and-effect scientific studies will increase understanding of ecosystem responses to restoration, particularly if responses are contrary to those predicted. The simulation modeling and the monitoring provide an objective means of testing the validity of the conceptual models and hypotheses, reducing scientific uncertainty, identifying new research priorities, and modifying restoration actions. This, in effect, is adaptive assessment.

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Performance Measures

Developing performance measures requires the identification of a set of biological and physical parameters that collectively represent the response of the system to restoration efforts over a range of spatial, temporal, and ecological scales. Performance measures were used in the feasibility phase of the CERP (the "Restudy") to evaluate proposed alternative redesigns of the water management system. Performance measures will be used in the implementation phase of the CERP to evaluate how well specific parts of a project, once implemented, are meeting the fundamental restoration objective of restoring ecological integrity.

Performance measures used in the feasibility phase of the CERP were largely hydrological. Through RECOVER, ecological performance measures have since been developed for each of the attributes in the conceptual ecological models. These attributes include the combination of populations, species, guilds, communities, and ecological functions that collectively can represent the response of the system to restoration projects. Performance measures identify, for each attribute, the numerical, spatial, temporal, or organizational targets that serve as the foundation for determining the success of specific restoration projects.

Systemwide Science Program

The SCT is assisting the AAT in implementing a systemwide science program for restoration projects. The systemwide science program being developed has four components: (1) a long-term monitoring and data collection program, (2) cause-and-effect scientific studies, (3) simulation modeling, and (4) peer review. The science program will establish base line and trend data for a common set of biological and hydrological parameters and will address cause-and-effect relationships between restoration implementation and ecosystem response.

The systemwide science program is also being designed to build on current hydrological and ecological research programs being conducted by federal and state agencies in South Florida. Some of these research programs are briefly described below. Existing programs are regularly reviewed for compatibility of protocols, completeness of spatial and temporal coverage, and their adequacy relative to the proposed set of performance measures. Integration of the current science programs is expected to reveal the need to initiate new science projects, expand some existing projects, and terminate lower priority projects. Science programs will best reveal system responses to restoration projects if science is focused on performance measures specific to restoration.

Current Hydrological and Ecological Research Programs in South Florida

Some of the most important hydrological and ecological research programs currently being conducted in South Florida include those from the National Oceanic and Atmospheric Administration (NOAA); the Department of the Interior (DOI) through the National Park Service (NPS), the U.S. Geological Survey (USGS), and the U.S. Fish and Wildlife Service (USFWS; and the South Florida Water Management District (SFWMD).

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NOAA: South Florida Ecosystem Research and Monitoring Program (SFP)

At about the same time that the task force was convened, NOAA began developing a management plan for the Florida Keys National Marine Sanctuary (FKNMS), and a regional coastal science plan to respond to the late 1980s ecological changes in Florida Bay and its valuable fisheries nursery area, largely upstream of the sanctuary. The resulting SFP was specifically developed to address NOAA's responsibilities in the region, be consistent with the priorities of the restoration process, and be complementary to other state and federal programs that comprise the Interagency Florida Bay and Adjacent Marine Systems Science Program (FBAMS). The SFP commenced in 1994 and is expected to continue over the coming decades as South Florida ecosystem restoration is implemented. Projects are being conducted by federal investigators associated with the Ocean and Atmospheric Research / Atlantic Oceanographic and Meteorological Laboratory (OAR/AOML) and the National Marine Fisheries Service / South East Fisheries Science Center (NMFS/SEFSC), and by an extensive network of regional academic investigators.

Given the incomplete knowledge of the system and additional factors that defy rigorous prediction, a sophisticated and spatially extensive program of monitoring, research, and modeling in coastal ecosystems is needed to protect these systems through adaptive management. NOAA's basic mandates require that we address this need in light of the CERP, the Magnuson Act imperative to protect essential fishery habitat, and the recently implemented Tortugas Ecological Reserve ,with its relatively pristine waters, as well as the growing list of federally protected marine species.

Activities currently underway in NOAA's SFP to address NOAA and SFER/CERP priorities, which were specifically designed to complement other research and monitoring activities ongoing in the region, can be categorized into the following areas: scientific programs (long-term observations, targeted ecosystem research, socioeconomic research, data and information synthesis, and modeling) and programmatic elements (education and outreach and regional program integration). These activities are explicitly consistent with priorities expressed by peer reviews conducted by the Science Oversight Panel (SOP) for the Interagency Florida Bay and Adjacent Marine Systems Science Program (FBAMS), the Science Advisory Panel (SAP) of the FKNMS, and the National Research Council's CROGEE. Activities specifically include the monitoring and assessment elements that the CERP Monitoring and Assessment Plan assumes will be the responsibility of NOAA.

NOAA's research projects, administered by National Oceanic Service / Center for Sponsored Coastal Ocean Research (NOS/CSCOR) and supported with funds provided by NOS/CSCOR, OAR/AOML, and NMFS/SEFSC, were selected on the basis of an open competition via an announcement of opportunity in the *Federal Register*, followed by a technical mail review and panel evaluation of proposals. NOAA's financial contribution to the overall SFER/CERP efforts has not been great. However, with regard to the coastal marine ecosystem, NOAA has consistently exercised leadership and has been the major contributor to the interagency science effort. NOAA is specifically responsible for the coastal marine ecosystem, its living marine resources, its protected species, and the FKNMS, including the recently implemented Tortugas Ecological Reserve, the nation's largest marine reserve. The NOAA SFP established a coordinating office in Key Largo with an executive director. Its program manager (and a satellite office) are located in Miami at OAR/AOML.

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While NOAA is specifically responsible for the coastal marine ecosystem and its living marine resources, additional federal, state, county, and municipal agencies all contribute and collaborate in significant ways. To note just a few of these contributions, three national parks encompassing coastal waters have their own science programs; FKNMS staff is involved in coordination of these programs within the NPS and with NOAA. The USGS conducts a range of coastal zone dynamics, paleoecological, groundwater, and geological studies. Florida state agencies include the SFWMD, the Florida Department of Environmental Protection (FDEP), and the Fish and Wildlife Conservation Commission's Florida Marine Research Institute (FMRI). The FMRI has a regional facility in the Florida Keys and conducts programs in ecosystem assessment and restoration and fisheries assessment, which contribute substantially to our knowledge of the South Florida coastal ecosystem.

The specific elements of the NOAA SFP Program are described in greater detail, below.

Long-term Observations

NOAA is supporting long-term observations of physical conditions, water quality, key benthic habitats, and key populations of fishery species, associated fish communities, and protected species provides resource managers with fundamental information about spatial and temporal patterns and variation of ecosystems, as well as interrelationships. Patterns in these data can show managers where focused ecosystem studies are needed to elucidate mechanisms underlying particular patterns and, in particular, to investigate anthropogenic and natural effects on ecosystem processes. Knowledge of patterns and processes enables managers to determine whether management actions are feasible and likely to have the intended effect.

Targeted Ecosystem Research

Studies underway comprise research to elucidate mechanisms underlying spatial and temporal patterns of ecosystems and fisheries as documented by long-term observational projects. Such studies are necessary to meet agency mandates, as identified in management plans and other documents that identify agency resource management priorities. Once there is sufficient knowledge of an ecosystem, managers can identify particular physical, chemical, and biological processes that merit directed investigations relevant to high-priority management objectives. These studies are essential to a management-directed understanding of South Florida coastal ecosystems. Targeted studies are also needed to develop appropriate performance measures with which to evaluate design alternatives in CERP and monitor coastal effects of project elements as they are implemented.

Our basic understanding of marine ecosystems lags far behind our knowledge of terrestrial and freshwater systems. We therefore cannot rely entirely on existing targeted studies to meet all our needs for science-based management. Peer reviews by the SOP, SAP, and CROGEE identify areas of research that need high-priority attention by funding agencies and the research community.

Socioeconomic Research

We know in general terms that the South Florida environment is a major contributor to the region's economy through tourism, recreational activities, and commercial fishing. However, we do not have an understanding of likely socioeconomic changes as a result of the CERP and

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associated environmental changes in Florida Bay and adjacent areas. Paleoecological studies have provided indications of changing floral and faunal distributions in association with past freshwater-management practices. This information and additional sources are being utilized in socioeconomic research to improve our understanding of consequences of the CERP to the South Florida economy. The program is in its infancy and will we expect be markedly extended over the next few years.

Modeling

Modeling studies need to be conducted to improve our understanding of coastal ecosystem processes and how these processes are influenced by human activities. Models are fundamental to developing predictive capability. They enable an analysis of the completeness of parameters provided by long-term observations and targeted ecosystem and fisheries studies. In South Florida, models are needed to organize and integrate existing information, indicate critical information gaps, build knowledge, evaluate alternative CERP designs, and help interpret data obtained from monitoring. Models are an essential component of adaptive management. Both physical and ecological models are needed for Florida Bay and other coastal systems.

Data and Information Synthesis

Efforts are underway to collect the data and information necessary to be used in developing comprehensive synthesis reports and products that are specifically designed to present scientific understanding of the South Florida ecosystem in forms that are both useful and understandable to restoration and resource managers. These synthesis products will provide the basis for evaluating the efficacy of CERP scenarios and measuring the effectiveness of current studies, and will guide the planning of future research and monitoring efforts.

Education and Outreach

A program of education and outreach is essential to provide a communication link between the South Florida public and the research community. Information from the program will enable citizens to make science-based decisions on issues that affect the region's coastal environment, in particular the FKNMS, living marine resources, and issues concerning protected species. The program will also provide information about freshwater, estuarine, and marine issues in the region and objective information to help stimulate changes in behaviors in support of effective restoration of the South Florida ecosystem.

DOI: Everglades National Park Critical Ecosystem Studies Initiative (CESI)

The U.S. Congress appropriated funds during fiscal year 1997 to establish a new DOI Critical Ecosystem Studies Initiative (CESI) under the U.S. National Park Service to support the South Florida ecosystem restoration initiative. The superintendent of Everglades National Park (ENP), as CESI manager, has been charged with the responsibility of administering these funds and assuring that they have been applied in an appropriate manner, yielding sound scientific results that both improve the management of DOI lands in South Florida and significantly contribute to our regional restoration program. The executive director of the task force serves as the principal advisor to the CESI manager on the program. Within the initiative, major categories have been established that are supported by appropriations as described by the annual DOI Cross-Cut

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Budget. A CESI coordinator and program category managers assist with the definition of science objectives, establishment of priorities, solicitation and selection of proposals and work plans, and coordination with federal, state, and local agencies to meet the goals and objectives of the initiative.

CESI supports studies conducted to provide physical and biological information, simulation modeling, and planning that are critical for achieving South Florida ecosystem restoration.

CESI supports major areas of ecological restoration related research, including investigations in the fields of coastal/estuary systems; contaminants and mercury bioaccumulation; ecological modeling, processes, and indicator species; hydrologic models; landscape patterns; and water-quality treatment.

DOI: USGS Greater Everglades Science Program, Place-Based Studies (PBS)

The USGS PBS Program in South Florida was initiated in 1995 and provides objective integrated science for managers who are seeking to restore natural functions and values of resources and the environment. In order to restore these functions, managers must have scientific information to resolve the complex resource problems that are before them. Resource managers use scientific information for several purposes. First, it helps to define the extent of environmental problems, and to distinguish changes caused by management actions from natural changes caused by climatic shifts, environmental succession, and natural climatic variability. Second, understanding how the ecosystem functions helps managers formulate possible solutions to those problems. Third, ecosystem models provide tools for determining which proposed actions will be the most effective in resolving the problems. Fourth, scientific information is necessary to develop the criteria and strategy for monitoring the success of management modifications.

The goals of the PBS Program are (1) to provide relevant, high-quality, impartial scientific information that permits resource-management agencies to improve the scientific basis for their decisions and to prevent or resolve resource-management conflicts and (2) to facilitate integration of scientific information.

Diversions of water and excessive nutrients and mercury within the Everglades have devastated bird populations and driven many species to the brink of extinction. In Florida Bay, declines in seagrasses, which hold sediment in place and provide habitat for fish, result in decreasing water clarity and declining fish populations. The U.S. Army Corps of Engineers (the Corps), the SFWMD, and other stakeholders are drawing up plans for restoring the Everglades and Florida Bay. USGS information and models help the Corps, the NPS, the FDEP, the EPA (U.S. Environmental Protection Agency) ,the USFWS, and the SFWMD predict the consequences of varied management alternatives, set ecological goals by providing yardsticks to measure the success of the restoration, and manage the natural resources of the system.

In FY 1999 the primary task of the USGS scientific program in South Florida shifted from primary data collection and research activities to enhancement of electronic availability of scientific information, and integration and synthesis of the scientific information that has been developed. The synthesis will integrate the accumulated scientific knowledge and understanding from USGS studies, help to chart the future scientific direction of the USGS program, and contribute to interagency synthesis activities to assist decision making for restoration of South Florida¹s ecosystem.

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In the Everglades and Florida Bay, the USGS provides a broad suite of information and computer models to its clients and partners through the task force and associated work groups. USGS hydrologic models, monitoring data, and ecosystem history results are used by the Corps and SFWMD for detailed planning. USGS seepage models and data help to predict the potential for flooding of urban areas due to cutting through levees to protect an endangered species population. Flows and water-quality information collected by the USGS will be used to help develop water-quality standards required before FY 2002 and monitor water flowing through land of the Miccosukee and Seminole tribes. USGS mercury information was used to develop a mercury monitoring plan by the SFWMD in FY 1999. USGS monitoring information and biological response models will be used by the Corps in a circulation model to estimate changes resulting from restoration. Communities in the Florida Keys use USGS information on nutrient and coral reefs to determine whether to modify their sewage-disposal practices. USGS information on Florida Bay is also used to refine the state's environmental monitoring programs and to improve the understanding of sediment resuspension and seagrass community changes. USGS hydrologic and geologic baseline information also helps determine water supply potential for increasing populations on the west and east coasts, and potential effects of reductions of water flow into Biscayne Bay National Park.

Specific USGS PBS in South Florida include the following research programs: ACME (Aquatic Cycling of Mercury in the Everglades; ATLSS (Across Trophic Level System Simulation); Ecosystem History; SICS (Southern Inland and Coastal Systems); and TIME (Tides and Inflows in the Mangrove Ecotone Model Development).

DOI: USFWS Multi-Species Recovery Plan (MSRP)

A challenge for ecosystem restoration and an important science application issue is how to protect and enhance the status of over 60 federal and state listed species while, at the same time, altering regional hydropatterns to achieve landscape-scale recovery of natural systems. Population declines in most listed species are thought to have occurred due to loss or degradation of essential habitat. Some listed species have changed their ranges and habitats substantially in order to compensate for effects that urban, agricultural, and water-management practices have had on their original habitat. Responding to changes in water depth and distribution patterns, these species have come to depend on different areas of the managed system than they used in the natural system. Although the overall expectation is that system restoration will improve habitat conditions for all listed species, the restoration implementation period may create short-term stresses on those species that may have to relocate again to adjust to restored hydropatterns.

The USFWS is leading the development of an integrated, comprehensive, multi-species recovery plan for the entire Kissimmee to Florida Bay basin. The purpose of the plan is to anticipate and plan for potential responses by listed species and to improve the design of the ecosystem restoration plans relative to recovery objectives. The MSRP identifies the strategies and thresholds that will best protect listed species in South Florida as regional ecosystem restoration programs are planned and implemented. The draft plan contains two sections. Part I consists of species accounts for all listed species, describing their biology and status and establishing the recovery goals and environmental compliance guidelines for each species. Part II relates the habitat requirements of the listed species to the landscape characteristics of South Florida, identifies specific land management actions necessary to recover listed species, identifies

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jeopardy thresholds, and proposes multi-species recovery strategies in the context of long-term objectives.

The Multi-Species/Ecosystem Recovery Implementation Team (MERIT) will develop an implementation plan for South Florida to prioritize the recovery actions as identified in the MSRP from an ecosystem perspective, and recommend and fund recovery and restoration activities.

SFWMD: Okeechobee / Everglades / Florida Bay Watershed Management Program

The SFWMD's Watershed Management Program seeks to integrate the SFWMD mission responsibilities within a watershed context,. that is, to incorporate watershed dynamics, ecosystem functions, and conservation biology into the decision-making process. The goals of watershed management are to (1) provide integrated scientific, planning and engineering support to assist policy makers with management decisions and project development; (2) ensure that scientific, planning, and engineering efforts are well-coordinated toward achieving water quality, water quantity, flood protection, and environmental restoration project goals; and (3) provide interdisciplinary management of projects from conception to completion. Watershed management efforts are under way in the South Florida ecosystem in the areas of nutrient enrichment; the effects of water level and flow management on wetlands, lakes, rivers, and estuaries; alternative water quality technologies; and predicting ecosystem responses to environmental restoration efforts.

SFWMD Successful Examples of Applied Science

A prime example of the Applied Science Strategy using adaptive management is the success story of the Everglades Nutrient Removal (ENR) Project. As part of the Everglades Forever Act (EFA) requirements, the ENR, an experimental marsh, was constructed to monitor and improve hydrologic, water quality, and vegetative conditions in the Everglades. Runoff from the Everglades Agricultural Area (EAA) was routed through an inflow canal for treatment in the ENR project. Phosphorus is naturally removed in aquatic systems by deposition and/or aquatic plants. As water passes through the ENR treatment areas, phosphorus levels are effectively reduced below 25 parts per billion (ppb). The information obtained from the ENR project was used to design and construct stormwater treatment areas (STAs), mandated by the EFA and key to improving water entering the Everglades system. The ENR Project's performance is constantly evaluated and new information is used to further restoration efforts.

Several research projects on the ability of cattail to invade the remnant Everglades have been completed. Cattail can survive and likely displace sawgrass under high-water conditions because cattail can pump air down into their roots to compensate for low-oxygen concentrations. However, this pumping ability comes at an energetic cost and requires additional phosphorus. These findings help explain why cattail invades the landscape so successfully under conditions of higher water levels and nutrient subsidies from fire, soil compaction, or stormwater enrichment.

Progress has been made toward understanding submersed aquatic vegetation in Florida Bay. It was previously thought that as Everglades restoration progressed, increased freshwater flow to Florida Bay might stress *Thalassia* seagrass (turtlegrass) beds by lowering salinity. However, healthy populations of *Thalassia* have been found in areas of maximum Everglades freshwater

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inflows, despite periodic low salinity and inflow of dark, tannin-colored waters that can reduce light levels in Florida Bay.

Research on the historical salinity in southern Florida Bay has formed the basis for the CERP Florida Keys Tidal Restoration Project.

Muck fire risk and wading bird nesting were combined to evaluate the ecological risks associated with alternative drought management plans.

Some of the SFWMD restoration projects include: Holey land regulation schedule, Rotenberger regulation schedule, STA monitoring and research, modified water deliveries project, C-111 project, long-term ecological research, Florida Bay minimum flows and levels, tree island hydrologic needs and research, wading bird hydrologic needs, water conservation area (WCA) historical tree island mapping and vegetation mapping, and ridge and slough research, among others.

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